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The No-Shaft Drive: NEL and Hydrostatic Transmission

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The major part of this issue of *New Technology* has been devoted to a feature on hydrostatic transmission. The Special Projects Division has earned for the National Engineering Laboratory an international reputation in this field. Some of this work is described here.

Mechanical drive and the designer

To operate effectively, the transmission or drive of a machine must slot into three basic requirements: a path has to be provided along which power can be transmitted from the engine to the device driven (the drive-line function); the engine and device driven have to be connected and disconnected smoothly (the clutch function); and the speed and torque of the device being driven have to match the characteristics of the engine (the change-speed function). For certain applications this specification might have to be extended to include such secondary requirements as transmission- and engine-braking facilities, ease of control, the ability to withstand the effects of continual stop/start operation, and the ability to withstand shock loading. To satisfy these requirements the design engineer has to make use of a judicial selection of clutches, fluid couplings, change-speed gearboxes, torque converters, universal couplings, propeller shafts, differentials, half-shafts, etc; and around these he designs his machine. He has become accustomed to thinking of mechanical drive as the accepted method of power transmission; and this type of drive does, of course, serve its purpose adequately, *provided that the machine in question has been designed to embody it*. This proviso is important, for it is invariably difficult—and, more often than not, prohibitively expensive—to fit a mechanical drive (remembering all its shafts, sliding joints, couplings, gearing, chains and belts) into a design in which the location of the drive has not initially been given overriding consideration. In the case of vehicle design, this means that the engineer has to decide where the drive line can go before he can start thinking about where to position the prime mover, driver and truck—a situation which is the modern equivalent of putting the cart before the horse, and certainly a reflection of the fact that we have not yet escaped from the horse/shafts/cart concept of design. Little wonder, then, that a fourth basic requirement has begun to emerge: that the transmission should impose the minimum of constraints on the designer, leaving him free to concentrate his design on such operational aspects as safety, productivity and reliability;

Mr. Michael Heseltine, Minister for Aerospace and Shipping, tries out one of the dumper trucks fitted with hydrostatic transmission.

which brings us to hydrostatic transmission. Hydrostatic drive obviates the need for a shaft and an axle differential, and can therefore be routed along any desired line; all in all, it is probably the nearest the designer is going to get in the foreseeable future to the ideal of an 'invisible' transmission.

Hydrostatic drive

The principles of hydrostatic drive are simple, even if their practical exploitation is somewhat more complex. They involve the delivery of fluid from a series of positive-displacement elements to another series of similar (but not always identical) elements in another mechanical combination forming a motor. The operating principles can be seen from Figures 1 and 2. In

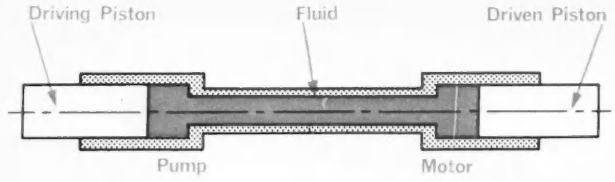


Figure 1. Principle of linear hydrostatic transmission.

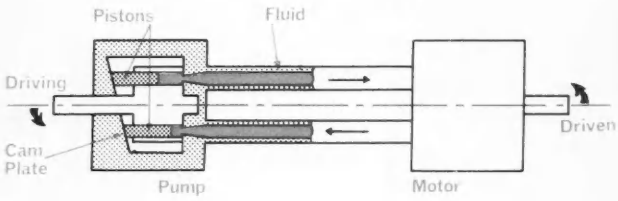


Figure 2. Principle of rotary hydrostatic transmission.

Figure 4. Redesigned dumper with NEL hydrostatic drive.

Figure 1 a close-fitting plunger pushes fluid from a container through a pipe into a similar container to move a corresponding plunger. Figure 2 shows how, by connecting several of such elements in a rotary mechanical sequence, power can be transmitted from one unit to another remote from it. If the piston areas in the driving unit differ from those in the unit being driven, but the strokes are equal, the speeds of the two units will differ in the same ratio as the areas of the pistons. When the strokes are not equal, the speed ratio will be the same as the ratio of the piston displacement of the driving unit to that of the driven one. When the piston displacements are changed in relation to each other (eg by a mechanical device which changes the stroke), the speed ratio becomes variable, and, because the change in the speed ratio is related directly to the change in stroke, this variable speed ratio can be made stepless.

The pumps and the motors they drive are of either fixed or variable displacement. Fixed-displacement pumps are generally of gear or vane type and are relatively cheap. Coupled with motors of the same type, they provide a remote fixed-ratio drive, to which a clutch function and reverse operation can be added by means of valves. Simple multi-speed transmissions can be produced by bringing one or more fixed-displacement pumps or motors into action in sequence. Variable-displacement pumps are of axial-piston, swashplate and tilting-head type. Variable-displacement motors are either similar to the pumps which drive them (in which case they may require a reduction gear to achieve the desired output torque) or of low-speed radial-piston type (in which case they are capable of developing a high torque without reduction gear). Used in combination with fixed-, variable- or multi-displacement motors, variable-displacement pumps provide a drive offering a fully variable ratio, ease of control, and transmission of full power irrespective of engine speed. By and large, then, the designer now has at his disposal a drive with all the flexibility inherent in the absence of shafts, bearings and joints, plus numerous other advantages. And the system has aroused considerable interest. Several manufacturers of agricultural tractors now offer an option between multi-ratio gearboxes and a fully-variable-ratio hydrostatic transmission, and many hydrostatically driven low-speed special-purpose and off-road vehicles are giving satisfactory service. A pump and motor can, of course, be mounted in one casing, and compact transmission units of this type, suitable for replacing conventional gearboxes, and capable of supplying the modified vehicle with an infinitely variable speed ratio, change-speed under load, and much greater manoeuvrability, have been available for some time—as, indeed, have relatively large, low-speed radial motors suitable for vehicle wheel drives. Nevertheless it must be admitted that these developments have found application mainly in special-purpose or limited-production machines.

Figure 3. Prototype dumper with NEL hydrostatic drive.

Reduce size and weight

It is not difficult to find explanations why. Take low-speed radial-piston motors. In principle they realise all the benefits of the hydrostatic approach, but they have not in the past made more than a marginal impact on the potential wheel-motor-drive market. What has been needed is a reduction in their size and weight to the point where their advantages can be fully exploited in practice. Happily the low-speed multi-lobe cam piston motors developed by the National Engineering Laboratory now meet this requirement. Carron Hydraulics Limited—one of the firms manufacturing hydrostatic motors to NEL's ball-piston design—is already marketing types capable of providing torque/weight levels of 14 lb-ft/lb (twice that of experimental electric units of comparable size), and there is every reason to believe that this ratio will be increased still further as higher torque requirements are met. Even at this stage of development, therefore, their motors can compete on level terms with existing mechanical hub drives from the point of view of size, and their availability has made the integration of a hydrostatic transmission into a machine at the design stage entirely feasible. This is important, since—hopefully—it is now recognised that hydrostatic drives can be exploited to full advantage only by going the whole hog and fully integrating them into a structure specifically designed to receive them.

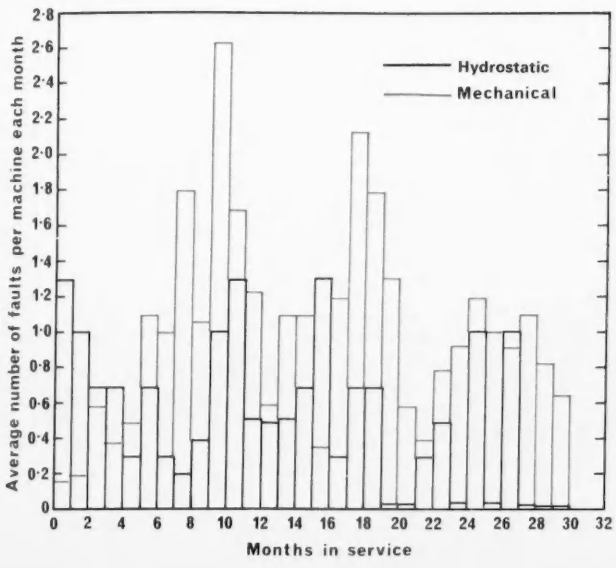
This is the reason why gearbox replacements have gained only limited acceptance. They undoubtedly possess all the attributes claimed for them; but they do not apparently outshine their well-established mechanical hydrodynamic competitors enough to warrant a switch to the hydrostatic system; and they cannot confer the one advantage which makes an overall hydrostatic transmission unique: design freedom.

Integrated fluid drive

The advantages of integration have been amply demonstrated in work at the National Engineering Laboratory. Figure 3 shows a small dump truck converted to hydrostatic drive. In trials the converted dumper did up to 34 per cent more work per unit time than the standard vehicle, had a lower maintenance load, and travelled as fast in reverse as forward. The engine delivered full power at any vehicle speed, and, since 'gear change' could be made under load, there was no danger of the dumper's stopping in boggy ground due to loss of drive through clutch displacement, and the driver was able to concentrate all his attention on steering. Nevertheless the basic design retained the unsatisfactory characteristics which were the legacy of the mechanical drive: for instance, its centre of gravity was still high, its ground clearance low and its weight distribution poor. A redesign of the dump truck to exploit the full potential of the hydrostatics produced the vehicle shown in Figure 4. The transmission units were industrially produced from a basic NEL design and integrated into the hubs, and the pump unit, together with the precharge unit, cross-over valves and relief valves, were integrated into the reservoir tank. The elimination of axle or differential enabled the load-carrying skip to be lowered further into the dumper frame, resulting in a lower centre of gravity and greater capacity—and all with more ground clearance. Because the engine did not have to be orientated towards an axle differential, it was possible to install the engine/pump combination transversely across the axis of the vehicle at a point which conferred the optimum weight distribution, so, of course, improving adhesion and increasing safety.

To assess the reliability of the dumper trucks under arduous service conditions, six of them (built by Barfords of Belton) were operated and maintained in the field by building-site personnel for a total of 12,000 hours. Faults on each machine were recorded and compared with those suffered by equivalent vehicles with mechanical drives. Not a single major transmission failure occurred in the hydrostatically driven trucks throughout the trial period, and maintenance was far less than with a mechanical drive. Figure 5 shows the fault record. The hydrostatic transmissions proved also capable of withstanding severe oil contamination without noticeable effect: Figure 6 illustrates the type of contamination which the dumper truck endured with aplomb.

Figure 5. Fault records of hydrostatically driven and mechanically driven dumpers.



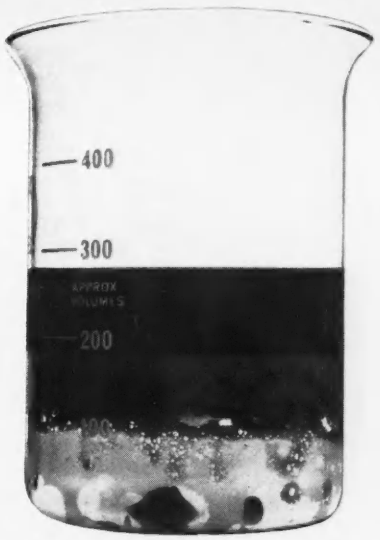


Figure 6. Sample of contaminated oil taken from a hydrostatically driven dumper after 1,000 hours' service.

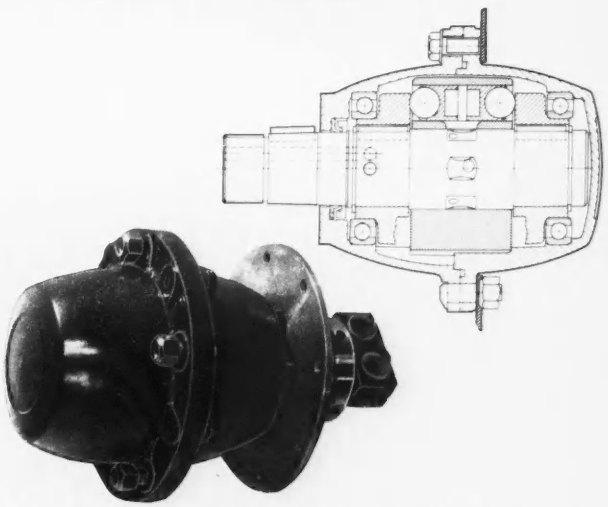


Figure 7. NEL-designed Carron Hydraulics' low-speed high-torque motor.

That NEL conducted the trials is not surprising, since through the activities of its Special Projects Division its name has become virtually synonymous with hydrostatic drive in the UK and it has won for itself an international reputation in the field.

NEL's Special Projects Division

Formed to provide an experienced team equipped to work in close collaboration with industry on selected projects, NEL's Special Projects Division has been active mainly in the fields

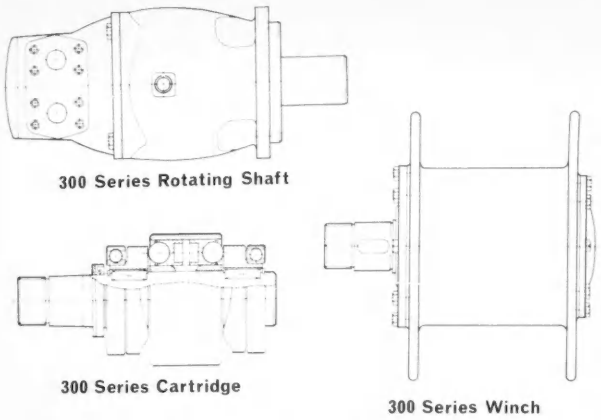


Figure 8. Some configurations of the basic NEL motor design.

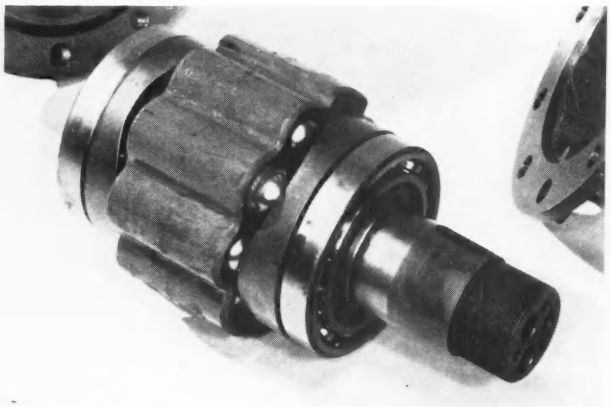


Figure 9. A cartridge assembly.

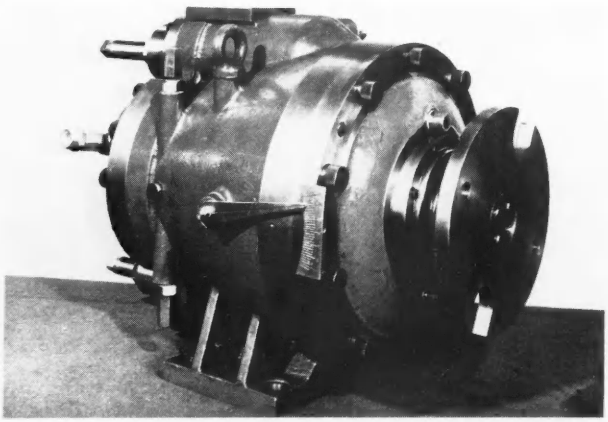


Figure 10. A hydrostatic pump designed for use in a ship's steering gear.

of fluid power, gas bearings and noise and vibration. The Division started its fluid-power operations in 1953, and has virtually grown up with the industry. Its work in the past has focused partly on the design and development of new units, and partly on the provision of direct guidance to industry (eg by analysing designs, assessing and testing industrial products, trouble-shooting, and consultancy activities), but the emphasis now is on the philosophy of integration, and the extrapolation of that philosophy to the production of new forms of machine designed around hydrostatic drive.

The account that follows describes some of the hydrostatic-transmission units developed at NEL and gives some examples of how such units have been integrated into machine structures and the benefits which have ensued.

NEL-designed commercially available units

A range of compact, reliable, low-noise motors and pumps designed by NEL are now being marketed commercially under licence. They are available in radial, axial or linear form, and the customer therefore has a choice to satisfy virtually every requirement. For example, the compact high-torque low-speed motors produced by Carron Hydraulics, Kirkcaldy, under licence to NEL, can be regarded as something of a break-through from the point of view of integrated design. To get more out of less—the approach adopted in developing the motors—the aim must be for extreme simplicity, and, as can be seen from Figure 7, each motor in fact consists of only five components: pintle, cam, rotor, casing and piston. The rotor has a series of nine cylinders, through-bored parallel to the main axis. Two face cams are keyed to the pintle on either side of the rotor, and opposed pistons in each of the cylinders operate on the cams. Each piston assembly consists of a short cylindrical piston, with a bearing ball fitted to a hemispherical seat in one end of the piston. The bearing ball operates in a grooved track in the cam and is slightly smaller than the piston. Each of the cams has three lobes, giving three working strokes and three turn strokes per piston—54 working strokes for every revolution of the rotor. Valve ports in the pintle admit high-pressure fluid to cylinders on a working stroke, and allow fluid to be exhausted from those cylinders with pistons on a return stroke. The particular motor illustrated in Figure 7 transmits up to 1 kN m (750 lb.-ft.) torque at a pressure of 21 MN/m^2 (3000 lbf/in^2), weighs 22 kg (48 lb.) and is designed to be fitted to wheels with a hub diameter of at least 159 mm (6.25 in). Its maximum designed operational speed is 500 rev/min. Other configurations of the basic NEL motor design are shown in Figure 8.

Versatile motor with wide application

The Carron Hydraulics' 300 series motors range in capacity from 160 to 330 cm^3/rev, depending on the type of cam fitted, though motors with capacities of 60-120 and 380-764 cm^3/rev are also available. Calculated on the peak pressure rating, the 300 series has a torque/weight ratio of 61 Nm/kg (20 lbf ft/lb)—almost twice that of other medium-pressure motors of the same capacity, and more than 30 per cent higher than that obtainable from high-pressure motors. The motor has features which make it extremely versatile and likely to find a wide range of applications. It can, for example, 'freewheel' with little noise and minimum power loss at speeds above 800 rev/min. This free-wheeling facility is achieved by shutting off the supply of fluid to the motor and allowing the ball-cam followers to be pushed away from the cam by the lobes on the cam track as the rotor rotates, and power loss is minimal because there is no pumping action from the pistons or circulation of fluid within the motor. Adding to the motor's versatility, and making it particularly attractive from the point of view of integration, is its availability in a configuration in which all the components, with the sole exception of the casing, are shaft-mounted in cartridge form (see Figure 9). In this cartridge form it can be inserted with ease into the driving assembly of a wide range of machines, the only connection between the cartridge elements and the driven machine being the keys which transmit the drive.

Leco Hydraulics produce a range of radial-piston ball motors operating on the same basic principles, and Lucas Industrial

Equipment Ltd. are also licensed by NEL to manufacture motors to this type of design.

The axial-piston 'swashplate' pumps developed by NEL find a variety of applications: eg coal-cutting-machine and, of course, vehicle drives. Manufacturers include Anderson Mavor Ltd., John Hastie and Company Ltd., and Serck Developments, and, as is the case with the low-speed motors, negotiations are in progress to license manufacture in the United States. Typical of units under development for licensees is the large pump for a ship's steering gear illustrated in Figure 10. Capable of an output of up to 400 hp, it will, with its smaller versions, replace a range of pumps designed 50 years ago.

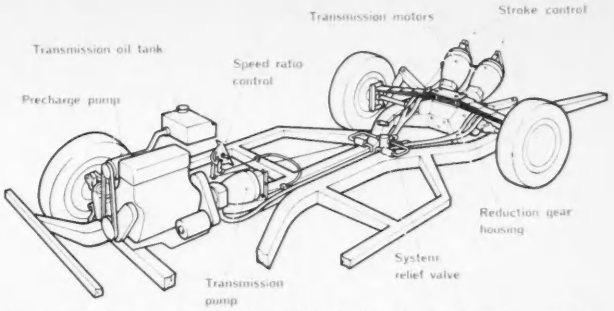


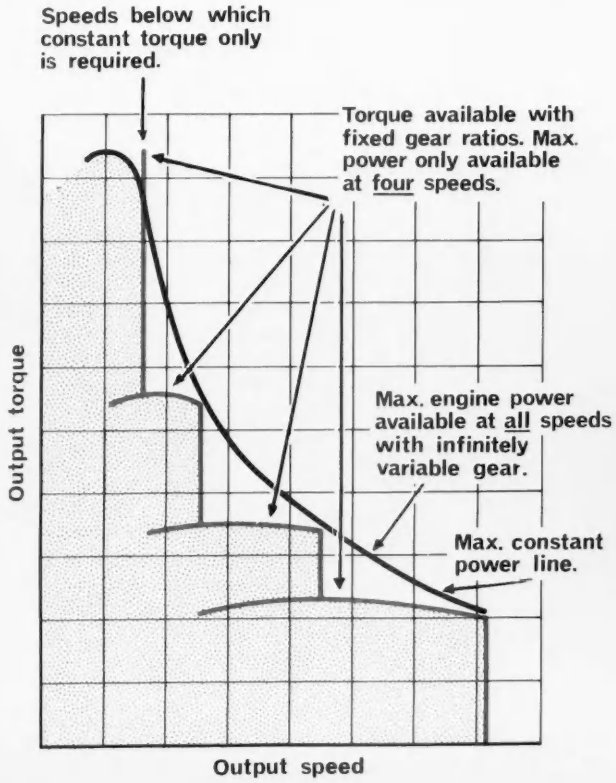
Figure 12a. Schematic view of the layout of the hydrostatic transmission fitted to a Triumph Herald saloon car.

Hydrostatic transmissions for road vehicles

The torque/speed characteristics of a typical vehicle with a four-speed gearbox are given in Figure 11. The curves show that, with fixed gear ratios, full engine power is available only at four points (corresponding to the maximum engine speed in each gear); in contrast, a hydrostatic transmission, with its infinitely variable gear ratio, offers an infinite number of 'gear curves'. For road vehicles, hydrostatic transmission has the following attractions: full engine power can be utilised over the whole speed range if required; gear changes can be made under load, so eliminating the need for a clutch; brake maintenance is minimised since braking is achieved via the transmission; all-wheel drive can be achieved much more conveniently than with mechanical transmission; and, of course, the designer has the greater freedom of layout and styling inherent in the 'flexibility' of the hydrostatic drive.

In 1961, to demonstrate the practicability and advantages of applying hydrostatic transmission to vehicles, NEL fitted a

Figure 11. Torque/speed characteristics of mechanically and hydrostatically driven vehicles.


Speeds below which constant torque only is required.
Torque available with fixed gear ratios. Max. power only available at four speeds.
Max. engine power available at all speeds with infinitely variable gear.
Max. constant power line.
Output torque
Output speed

Figures 12b and c. The photographs illustrate the compactness of the integrated wheel motor designs now available. They reflect the progress achieved since the Herald conversion, with its inboard-mounted high-speed motor and reduction gear.

Mk II light-weight transmission to a *Triumph Herald* saloon car. A schematic view of the layout is given in Figure 12a. The original gearbox and clutch were replaced by a variable-displacement swashplate pump of 2.2 in^3/rev capacity powered by the engine, and both rearwheels were driven by variable-displacement swashplate motors, of identical design to the pump, through a crown wheel and a pinion. Light-weight steel tubing was employed for the hydraulic circuit, and the motors were connected in parallel to allow a differential action between the wheels. Operating pressures and rotational speeds range up to 4000 lbf/in^2 and 4000 rev/min, respectively. The transmission ratio change is set by the driver, and the engine speed is controlled by the accelerator pedal (via a variable-speed governor), so that for maximum acceleration the engine can be kept at constant peak-power speed. Pump and motor swashplate are controlled from a rocking pedal operated by the left foot, and neutral is obtained by setting the pump swashplate to zero angle. Acceleration is achieved by increasing the pump stroke and/or decreasing the motor stroke. When the vehicle is cruising, the transmission speed ratio can be adjusted to give overdrive conditions, with the engine running at its most economic speed for the power required. The engine is braked by 'reversing' the system, the wheel motors then becoming pumps and the pump becoming a motor.

To obtain some idea of the breakthrough represented by the multilobe cam motor, and of the progress achieved since the Herald conversion, one need only contrast the conversion (and its inboard-mounted high-speed motors and reduction gear) with the integrated wheel-motor design shown in Figures 12b and 12c. NEL has employed a mini-car fitted with four such motors to assess the suitability of this type of transmission unit for road use, and against this background of experience is conducting several design studies with a view to incorporating hydrostatic drive in a range of vehicles, including a small utility on/off road car, public-service vehicles, earth-moving machines, large trucks and military vehicles.

Figure 13. Four-wheel-drive tractor conversion.

Figure 14. The photographs illustrate the manoeuvrability which NEL's Wildcat vehicle confers on the handicapped sportsman.

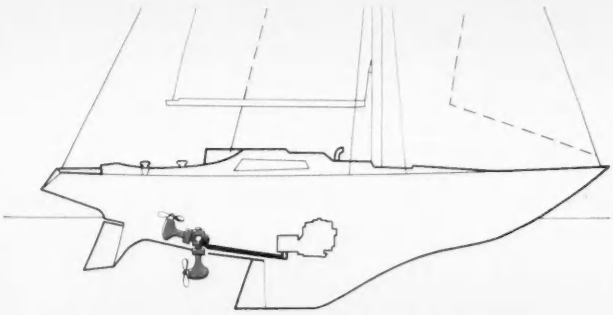
Dumper trucks

The service performance of the NEL dumper trucks specifically designed around a hydrostatic transmission exemplifies *par excellence* the technical and economic benefits which can accrue from integrating a hydrostatic-drive system into the structure of a machine at the design stage. The trials are referred to on page iii.

Four-wheel drive and auxiliary assist

The performance of any vehicle under marginal conditions can be substantially improved by recourse to all-wheel drive. As stated above, NEL ball-piston motors are already commercially available in sizes and weights comparable to motors used in mechanical wheel drives, and with power-to-weight ratios which make them applicable to all the commonly used wheel rims. Their facility to freewheel with the minimum of frictional drag and noise makes them ideal for converting the idle wheels of conventional mechanical two-wheel-driven vehicles to auxiliary drives. Their smallness enables the vehicle to be converted without alteration to the existing front-axle articulation and without reducing the ground clearance or the turning circle, whereas conventional mechanical-drive conversions adversely affect all these features, and are, moreover, invariably more costly.

The two front wheels of the agricultural tractor illustrated in Figure 13 have each been fitted with a 330 cm^3/rev axial-piston motor. The conversion was carried out by Carron Hydraulics. A simple fixed-displacement reversible pump driven from a ground-speed power take-off ensures that the front wheels are driven at the same speed as the rear wheels, independent of the gear or direction selected, and the change from two- to four-wheel drive and *vice versa* is achieved by means of a solenoid-operated valve actuated by microswitches. The conversion is based on the existing tractor hydraulic system,



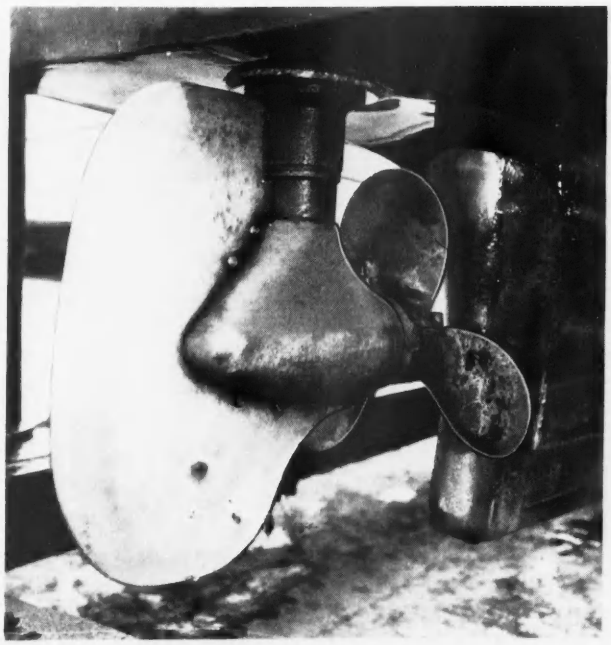


Figure 15. Pod-type propeller unit fitted to an 18-ft. (5.5-m) workboat.

and other attractive features include the low cost of the exercise, and lower maintenance requirements. The ease with which the change of drive can be made also opens up a whole vista of opportunities for providing heavy lorries, or even trailers, with auxiliary drive. For high-speed road work the auxiliary drive would, of course, freewheel.

NEL's 'Wildcat' vehicle

An embodiment of the NEL philosophy of integrated design, and typical of the projects undertaken for industry by Special Projects Division, the Wildcat vehicle (see Figure 14) provides all-terrain mobility for a handicapped sportsman. As a result of adopting hydrostatic transmission, and hence eliminating a shaft drive, NEL has been able to produce a unique vehicle satisfying such demanding and conflicting requirements as:

High ground clearance
15 in (381 mm) above ground
5¼ in (133 mm) above wheel centre

Low ground pressure
6 lbf/in² (0.4 bar)—equivalent to the pressure exerted by a standing man's foot

Good gradeability
40° slope

Exceptional stability
60° static tip angle

Light-weight monocoque construction

Front entry

Retractable seat.

The same basic design concept could be applied equally as well to such vehicles as personnel carriers, camera platforms, mountain-rescue ambulances and off-the-road fire-fighting auxiliaries.

Hydrostatic marine drive

You can eliminate the propeller shaft from ship design by replacing the conventional mechanical drive with hydrostatic transmission. Eliminate the need for a propeller shaft and you also eliminate restraints on engine position, and on hull shape and layout—hence NEL's work on hydrostatic marine drives. This work has resulted in the development of a basic pod-type propeller unit which

provides 360° steerability;
can be retracted to clear obstacles or to reduce drag when not required;
enables the engine to be flexibly mounted, so overcoming to a great extent the noise, vibration and propeller-thrust problems of a conventional drive;
simplifies control (a single lever provides stepless speed change and instantaneous reverse);
and simplifies propeller matching.

Figure 15 shows a 30-hp (22.5-kW) version of the pod fitted to an 18 ft. (5.5 m) workboat. Propeller drives of 145 hp are also available (performance curves are given in Figure 16), and development of larger units is under consideration. Potential applications include bow thrusters, tug drives and barge manoeuvring equipment.

Fork-lift trucks

The commercial availability of axial-piston motors small enough to incorporate into the wheels of fork-lift trucks has allowed the engineer to reap the advantages of hydrostatic transmission in this field also. The benefits include: a reduction in working-cycle time; infinitely variable control of speed in both the forward and reverse direction; instant reversal; reduction in maintenance requirements; reduction in operator fatigue; and elimination of the need for a chassis, enabling the truck to be broken down easily into sections for shipping. Fitting the wheel motors is an easy job, as Figure 17 shows. For this application a simple closed circuit, consisting of a variable-delivery pump supplying the two wheel motors (and with protection by crossline relief valves), is all that is required. The system is controlled by means of a simple rocking-pedal arrangement, coupled to the pump servo mechanism, and the truck is braked merely by reducing the pump stroke. To start the truck on a gradient of 16 degrees requires a peak pressure of about 21 MN/m² (3000 lbf/in²). The average pressure during the working cycle is less than 7 MN/m² (1000 lbf/in²). Trucks using the Carron/NEL system are manufactured by various firms, including Hudswell Badger Ltd. and Joshua Shaw & Sons Ltd.

Winches

The drawing in Figure 18 illustrates how a 764 cm³/rev motor in cartridge-assembly form can be used in a braked-winch unit. The motor is fitted directly into a drum mounted in a frame incorporating the disc-brake fail-safe unit and load-holding

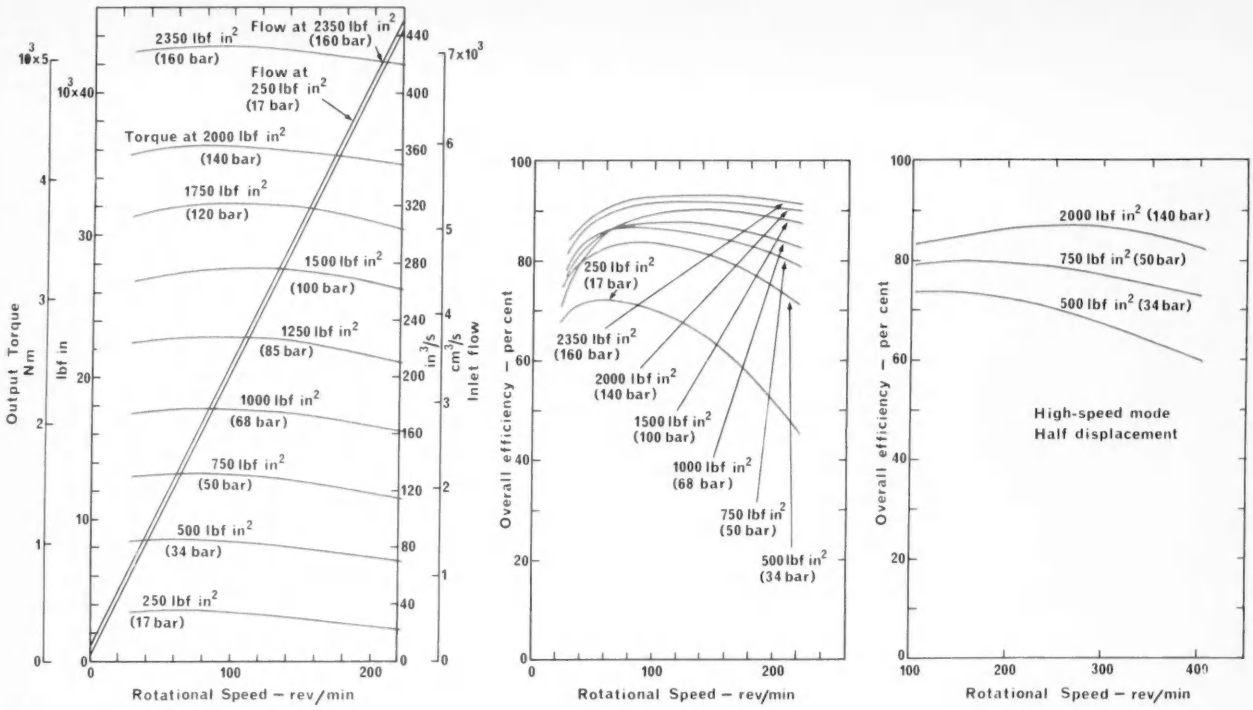
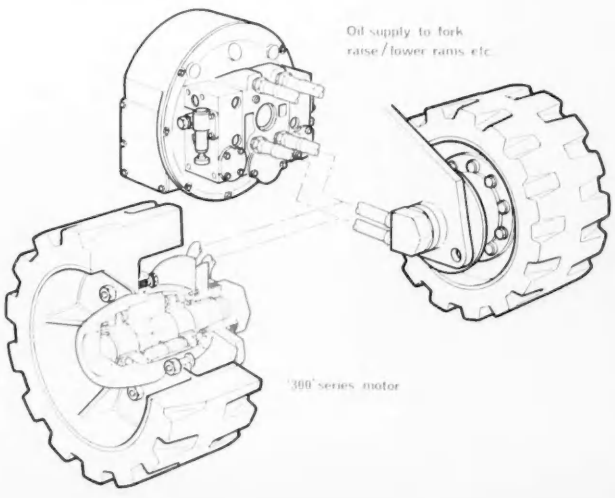

Flow at 2350 lbf in² (160 bar)
2350 lbf in² (160 bar)
Flow at 250 lbf in² (17 bar)
Torque at 2000 lbf in² (140 bar)
1750 lbf in² (120 bar)
1500 lbf in² (100 bar)
1250 lbf in² (85 bar)
1000 lbf in² (68 bar)
750 lbf in² (50 bar)
500 lbf in² (34 bar)
250 lbf in² (17 bar)
Output Torque Nm
lbf in
in³/s
cm³/s
Inlet flow
Rotational Speed – rev/min
Overall efficiency – per cent
2000 lbf in² (140 bar)
750 lbf in² (50 bar)
500 lbf in² (34 bar)
High-speed mode
Half displacement

Figure 16. Performance curves for a 145-hp (108-kW) propeller drive.

valve. The free-fall characteristics often required by winches of this type are readily available through the freewheeling facility available from multi-lobe axial-piston motors. For larger sizes of winch, cartridge assemblies are fitted into each side of the winch drum, so increasing the line-pull with very little increase in the diameter of the drum assembly. The load-holding arrangement consists of a differential-area relief valve shunted by a non-return valve to permit free flow when the load is raised. A pilot supply, fed from the motor inlet when the load is lowered, applies pressure to a piston, which opens the relief valve at one fifth of the pressure of the valve setting. The heat generated is lower than that associated with the use of a conventional directly operated counter-balance valve, and sufficient pressure can be maintained at the motor inlet to prevent cavitation.

Figure 19 illustrates how the overall operation of a trawl winch can be simplified by recourse to hydrostatic motors. Six 764 cm^3/rev motors are used to operate the drums and warping heads. Each drum and head is individually controlled, and, since the speed can be increased or decreased steplessly, there is no risk of gears being 'snatched' and damaged, as so often happens with conventional mechanical gearboxes. The warping head can be positioned in the optimum position from the design point of view (it does not have to be in line with the drum centres as it would with a mechanical system); the drum size can be made to match the requirements of the vessel; the

Figure 17. Hydrostatic transmission (below) for a fork-lift truck (left) (*Courtesy Hudswell Badger Ltd.*)



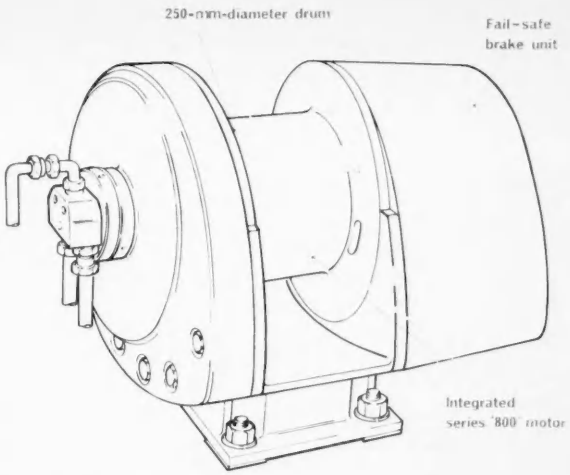


Figure 18. A braked-winch unit converted to hydrostatic drive by means of a motor fitted directly into a drum mounted in the frame incorporating the disc-brake fail-safe unit and load-holding valve.

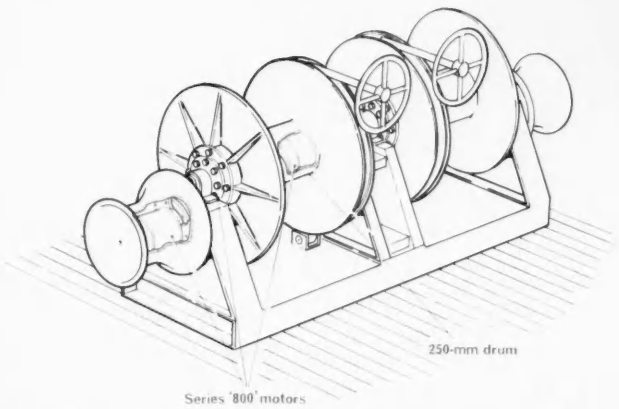


Figure 19. Six hydrostatic motors, fitted as shown, can greatly simplify the overall operation of a trawl winch.

area occupied by the winch is minimal; and, finally, control can be effected from a central station.

One last example of the versatility of the hydrostatic motor in its application to cranes: the jib of the truck-mounted crane illustrated in Figure 20 is slewed with high accuracy by means of a 764 cm^3/rev rotating-shaft motor with a double-shaft extension. The motor is mounted vertically, with the slewing pinion fitted directly to the top end of the shaft and the brake to the lower extension, producing a low-cost compact design very difficult to achieve with any other system.

Hydrostatic drives for machine tools

Because of their small size for a given displacement, NEL's axial ball-piston units are ideally suited for servo-motor feed-drive applications. NEL's linear ball-piston motor (a logical extension of the multi-lobe rotating ball-piston motor) offers advantages over conventional linear drives in various applications. In the case of machine tools, these are:

Stiffness characteristics are independent of stroke length.
Double-acting operation can be achieved in less than half the length of an equivalent double-acting hydraulic piston and cylinder.

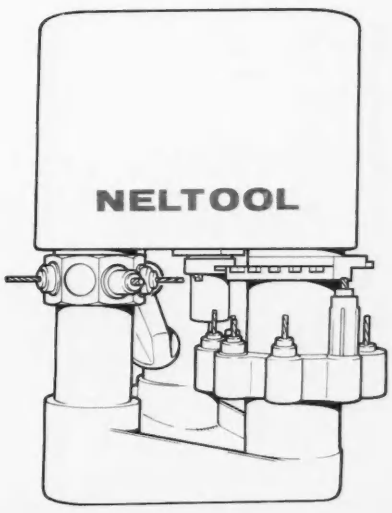
Figure 20. The jib of this truck-mounted crane is slewed with very high accuracy by means of a rotating-shaft motor with a double-shaft extension. (Courtesy James Connell (1969) Ltd.)

The bending moments set up by cutting forces within the machine-tool structures are not so great.
Arcuate motions can be achieved by constructing the cams in circular form.

The benefits can be fully realized, of course, only if hydrostatic units are integrated into the machine tool at the design stage. NEL undertook a design study with this aim in view, and this study eventually resulted in the development of a spindle module embodying rotational, positional and index-cutting tools. The NELTOOL multi-axis machining centre is one application of this spindle module.

In the NELTOOL design (see Figure 21) NEL has produced a basically new type of machine—a compact unit with no shafts, gearing or chains, and with all the advantages inherent in their absence. Incorporating standard NEL rotary and linear

Figure 21. NELTOOL—NEL's hydrostatically driven multi-axis machining centre.



hydrostatic drives, NELTOOL can perform the following operations:

Facing
Sliding
Contour milling
3D milling
PCD drilling and tapping
Slotting and keywaying.

NELTOOL has a vertical configuration, with the spindle module mounted at the top, supported by three large-diameter columns—a relatively simple structure affording a high degree of accessibility. The tooling is carried by the three columns. All machining operations at right angles to the principal axis of the machine are carried out with tooling facilities of maximum stiffness. Other operations are preformed by a universal facility which can be positioned to operate at any angle of orientation.

The turning station, which carries 15 tools for end and side working, is supported on its column by a double conical hydrostatic bearing. Supported on the same column, also by a double conical hydrostatic bearing, is an end-working station with 8 tools for milling, drilling and boring operations. A side-working station carries 7 tools for milling and drilling operations, and the universal milling and drilling station carries one tool only, but incorporates a feed.

More information on NEL and hydrostatic drive

NEL's Special Projects Division is ready to undertake work on any aspect of hydrostatic drive (including trouble shooting, design studies, R & D, prototype manufacture, and testing), in conjunction with or on behalf of commercial firms or organisations. It would welcome the opportunity of quoting a price and delivery date for any project, or, where appropriate, negotiating licences. More information can be obtained by contacting the Director, National Engineering Laboratory, East Kilbride, G75 OQU (Tel: East Kilbride 20222).

Items illustrating many of the developments in hydrostatic transmission referred to in this article will be on display in the Fluid Power section of this year's Hanover Fair (April 26-May 4, 1973), and the members of NEL's Special Projects Division manning the stand will be pleased to discuss with visitors any of the Laboratory's work in this field.

news

Systems reliability course

The Systems Reliability Service of the United Kingdom Atomic Energy Authority is running, in collaboration with Liverpool University, a course on Reliability Assessment, from April 2-13, 1973. This will be the sixth course for industry run by SRS in the past two years and covers techniques applied to both nuclear and non-nuclear industries.

The course is intended for engineers and technologists of all disciplines concerned with achieving adequate reliability in complex equipment and systems. It is designed to appeal to designers, operators, managers and support staff. The course will cover the mathematics of probability and its application to testing and maintenance of equipment and prediction of failure rates; system synthesis and modelling, including electrical networks; computer analysis techniques; data bank services, and other aspects. The lecturers will include staff from the SRS and the universities of Liverpool, Birmingham, Bradford and Manchester.

Course fee is £150 (£125 for SRS associate members), exclusive of VAT and accommodation

Applications: Mr. A. C. Wilson, Systems Reliability Service, UKAEA, Wigshaw Lane, Culcheth, Warrington, Lancashire, Tel: 0925 31244, ext. 208.

Investigation of Britain's mineral resources

An exploration programme to provide preliminary information on areas of potential economic mineralisation in Great Britain is to be undertaken by the Natural Environment Research Council on behalf of the Department of Trade and Industry. This follows the customer/contractor approach for Government research and development described in the recent White Paper *A Framework for Government Research and Development* (Cmnd. 5046, July 1972).

In the first instance there will be a three-year programme costing £1.3 million, the work being carried out by the Institute of Geological Sciences (IGS). The programme aims at providing basic geological information on which subsequent mineral exploration could be based. Together with the information supplied by mining companies receiving assistance under the Mineral Exploration and Investment Grants Act 1972, the programme will give the Government more comprehensive information on the country's mineral resources and will contribute to long-term economic and land use planning.

Initially, work will be concentrated in five areas which IGS has identified as areas where economic deposits of minerals may occur—Northern Scotland, South West Scotland, the south west peninsula of England, the Pennines and Wales (Anglesey and Central Wales). Full details will appear in the IGS Report Series.

More information: Institute of Geological Sciences, Bashley Road, London NW10.

International Organisation of Legal Metrology (OIML)

The following document has been circulated by OIML to member-countries for comment:

Title: Legal Units of Measurement.

Reference: Draft International Recommendation.

Copies may be obtained from Standards Weights and Measures Division, Department of Trade and Industry, Abell House, John Islip Street, London SW1P 4LN.

Advisory Board for Research Councils

Mrs. Margaret Thatcher, Secretary of State for Education and Science, has announced the names of members of the Advisory Board for the Research Councils which has replaced the Council for Scientific Policy. The Chairman is Prof. Sir Frederick Dainton, Dr. Lee's Professor of Chemistry, University of Oxford. Other members of the Board are: Sir Kenneth Berrill, Chairman, University Grants Committee; Dr. W. R. Boon, Managing Director, Plant Protection Ltd. (ICI); Dr. R. H. L. Cohen, Chief Scientist, Department of Health and Social Security; Sir Brian Flowers, Chairman, Science Research Council; Dr. J. A. B. Bray, Secretary, Medical Research Council; Prof. F. H. Hahn, Professor of Economics, University of Cambridge; Dr. W. M. Henderson, Secretary, Agricultural Research Council; Prof. Sir Alan Hodgkin, President of the Royal Society, and Dr. P. E. Kent, Exploration Manager, British Petroleum Co. Ltd.

New reference tables for thermocouples

Following international agreement, new reference tables for thermocouples are being introduced, and are to be published in the United Kingdom by the British Standards Institution. The new tables, based in part on work done at the National Physical Laboratory, take into account agreed changes in the composition of some platinum and base-metal wires used in thermocouples.

A meeting to discuss the proposed changes was held recently under the auspices of the British Calibration Service (BCS). Representatives of thermocouple and wire manufacturers, of users, of the National Physical Laboratory, of the British Standards Institution, and of BCS approved calibration laboratories, met to consider the timing and implementation of the changes.

The new reference tables, four of which will be published by BSI about March 1973, will incorporate the change of temperature scale as well as the changes due to the new materials being introduced. The UK manufacturers of thermocouple wires are making the new material compositions available now and intend that these should supersede the previous wires from July 1, 1973.

More information: British Standards Institution, 2 Park Street, London W1A 2BS. Tel: 01-629 9000.

NCC and Post Office co-operate to develop on-line systems

To assist computer professionals in making more effective use of data on-line communications in the spheres of publications and education, the National Computing Centre and the Post Office have reached agreement for close liaison in the development of facilities.

In the publications field, the NCC and the Post Office will work together to produce complementary guidelines covering various on-line techniques which may affect systems design. Detailed information about existing on-line systems within the United Kingdom is being collected by the NCC so that all aspects of the liaison may reflect current UK needs and practice.

The NCC would welcome offers of assistance from other organisations which have installed on-line facilities—either in-house or to a bureau

—and which would be willing to share their experience. It is hoped that the research which supports the liaison will define techniques and, where possible, identify standards to be employed in the design of on-line systems. A working party formed by the NCC Midland Regional Committee has been responsible for initiating much of this work.

In the education field, the Post Office will work with the NCC in a jointly-developed and jointly-presented advanced level course in the design of on-line systems. The advanced course will combine the instruction in data transmission given in the present Post Office training with extensions to the current NCC course, especially in the areas of systems techniques, network design and relations within the data base. Initially there will be an exchange of lecturing staff on the current series of courses presented by the Post Office and the NCC's Education and Training Division.

The liaison is seen as the beginning of authoritative training in the increasingly related areas of computers and communications.

More information: Mr. Peter Wheeler, Head of Public Relations, The National Computing Centre Ltd., Quay House, Quay Street, Manchester M3 3HU. Tel: 061-832 9731.

Quality Technology Information Service

A subscription information service—QUALTIS—covering all aspects of material quality testing is being provided by the Harwell Nondestructive Testing Centre of the Atomic Energy Research Establishment. The service is based on an extensive collection of more than 10,000 periodical articles, conference papers, reports, standards and patents on nondestructive testing and materials evaluation topics which is continually being updated.

In addition to having access to this specialised documentation, subscribers to QUALTIS can obtain confidential detailed reports relating to specific problems, making use of the expertise of NDT Centre staff in the applications of conventional and specialised inspection methods to many types of industrial product. Members of QUALTIS will also receive copies of a new year book *Quality Technology* (see below). Annual subscription is £50 for an individual, firm or identifiable unit within a large organisation.

More information: Qualtis Manager, The Nondestructive Testing Centre, Atomic Energy Research Establishment, Harwell, Didcot, Berks. OX11 ORA. Tel: Abingdon 4141, ext. 2470.

Quality Technology year book

Quality Technology '73 is the title given to the first of a planned series of year books to be published by the Nondestructive Testing Centre (NDT) at the Harwell Atomic Energy Research Establishment. It is intended to serve as a useful directory for those in industry responsible for quality control as well as a reference source of background data for those more closely involved in designing and applying inspection and testing procedures to monitor quality in a manufacturing process. During the past six years the NDT has built up an information store of well over 10,000 items of technical information carefully classified by content which is readily available to industrial enquirers. The year book is a development of this service, the operation of which has helped in deciding what should be contained in the book. Compilation and editing has been carried out by R. S. Sharpe, H. J. Langton and W. A. Dowden.

There is a 374-page information section, the contents of which include: an annually updated guide to suppliers of equipment and services; detailed buyers' guides to particular types of equipment (those in the 1973 edition cover X-ray sets and ultrasonic thickness gauges);

(*continued on next page*)

Requirements Boards meet for first time

The first meetings have been taking place of the new Requirements Boards. The setting up of the six boards by the Department of Trade and Industry was announced by Mr. Michael Heseltine, Minister for Aerospace and Shipping, on October 16, 1972 (*New Technology*, October 1972). The photographs shown here were taken at the inaugural meetings of the Mechanical Engineering and Machine Tools Requirements Board and of the Computers, Systems and Electronics Requirements Board.

Chairman of the first of these two Boards is Mr. J. W. Atwell, Chairman of the Engineering Division, Weir Group Ltd. Independent members of the Board are: Mr. J. Atherton, Managing Director, Asquith Division, Staveley Industries; Mr. Oscar Hahn, Chairman, GKN Bolts and Nuts Ltd. and GKN Screws and Fasteners Ltd; Prof. L. Maunder, Head of Department of Mechanical Engineering, University of Newcastle-upon-Tyne; Mr. R. W. Mellor, Chief Engineer, Engine Engineering, Ford Motor Co.; Mr. D. B. Welbourn, Department of Mechanical Engineering, University of Cambridge; Mr. H. A. Whittall, Managing Director, Amalgamated Power Engineering Ltd., and Dr. D. T. N. Williamson, Director of Research, Molins Ltd. Official members of the Board are: Mr. M. G. Fletcher, Chief Engineer, RAE, Farnborough, MOD (PE); Mr. D. Harrison, Computers, Systems and Electronics Division, DTI; Mr. P. J. L. Homan, Mechanical Engineering Division, DTI, and Mr. L. H. G. Sterne, Deputy Director, National Engineering Laboratory, DTI.

Chairing the Computers, Systems and Electronics Requirements Board is Mr. J. W. Nichols, Under Secretary at DTI. Independent members of this Board are: Mr. A. d'Agapeyeff, Chairman, Computer Analysts and Programmers; Mr. H. S. Brown, Manager, Electrical and Control Engineering, British Steel Corporation; Dr. E. Margaret Burbidge, FRS, Director, Royal Greenwich Observatory; Mr. R. J. Clayton, Technical Director, General Electric Company; Dr. R. M. Needham, Assistant Director of Research, University of Cambridge Computer Laboratory; Mr. J. H. Robertson, Director, Inter-Bank Research Organisation; Mr. M. W. Sage, Laboratory and Engineering Manager, ICI Corporate Laboratory; Dr. A. Shepherd, General Manager, Electronic Components Division, Ferranti Ltd., and Mr. M. B. Williams, Deputy Director of Engineering, Post Office. There are four official members of the Board—Dr. E. T. Goodwin, Deputy Director, National Physical Laboratory; Dr. D. H. Parkinson, Deputy Director, Royal Radar Establishment Malvern; Mr. S. W. Spain, Under Secretary, Civil Service Department, and Mr. K. R. Stowe, Under Secretary, Department of Health and Social Security.

Above: The first meeting of the Mechanical Engineering and Machine Tools Requirements Board. Front row: left to right: Mr. J. Atherton, Dr. D. T. N. Williamson, Mr. J. W. Atwell (Board Chairman), Mr. D. B. Welbourn and Mr. D. Harrison. Back row, left to right: Mr. John Hall (Board Secretary), Mr. P. H. Stephenson (RR2 Division, DTI), Mr. E. Barlow Wright (RC1 Division DTI), Mr. J. E. A. Harrison (acting Board Executive Officer), Mr. L. H. G. Sterne, Mr. M. G. Fletcher, Mr. R. W. Mellor, Mr. P. J. L. Homan and Mr. Oscar Hahn.

Below: The Computers, Systems and Electronics Requirements Board meets for the first time. Front row, left to right: Mr. M. B. Williams, Dr. A. Shepherd, Mr. J. H. Robertson, Mr. J. W. Nichols (Board Chairman), Mr. A. d'Agapeyeff, Mr. R. J. Clayton and Mr. M. W. Sage. Back row, left to right: Mr. J. Harrison (Board Executive Officer), Mr. K. R. Stowe, Mr. H. S. Brown, Mr. S. W. Spain, Dr. D. H. Parkinson, Dr. R. M. Needham, Dr. E. T. Goodwin and Mr. E. Barlow Wright (RC1 Division, DTI).

details of Government establishments and research associations and other institutions, societies, organisations and committees, both in the UK and overseas, involved in quality technology; NDT technique standards, reference books, conference proceedings and periodicals; notes on current relevant legislation, including safety and protection; and selected technical data, formulae, graphs and tables useful in the day-to-day practice of quality technology. In addition to the large information section, there is a diary section in which there are marked various appropriate events taking place during the year. In future editions it is intended to broaden the book's coverage.

Copies (UK price £5) and further information: Mr. W. A. Dowden, QUALTIS Nondestructive Testing Centre, AERE Harwell, Didcot, Berkshire OX11 0RA. Tel: Abingdon 4141, ext. 2470.

CAD Centre's new service for North West

The Department of Trade and Industry's Computer-Aided Design Centre has established a new service for users in North West England, providing engineering firms and research workers with easier and cheaper access to the Centre's computer systems.

Through a communications concentrator at Risley near Warrington a local telephone call will now connect users from most of the Manchester and Liverpool telephone areas to the CAD Centre at Cambridge and provide access to an expanding network of linked processors. Users with a teletype or graphic display terminal can make direct use of this service. For those who do not have such facilities, the CAD Centre—with the assistance of the National Computing Centre—has set up a terminal centre at NCC's computer installation in Oxford Road, Manchester.

More information: The Chief Consultant, Computer-Aided Design Centre, Madingley Road, Cambridge CB3 0HB. Tel: 0223 63125; telex: 81420.

NASA to launch DTI satellites

Formal arrangements have been completed for NASA to launch DTI satellites on a repayment basis. A contract will be implemented for each launching. A Memorandum of Understanding was negotiated between DTI and NASA following the decision to end the Black Arrow launcher programme.

The first satellite to be launched by NASA under the new arrangements will be X4, which is designed to prove in orbit a new 3-axis attitude control system, together with a deployable solar array and a number of experimental sensors. Launching is scheduled for March 1974, on a NASA Scout vehicle. The prime contractor for the X4, is Hawker Siddeley Dynamics Ltd.

Plans for subsequent DTI satellites, forming part of the National Space Technology Programme, are being considered in the light of the present discussions on a unified European space programme. Hawker Siddeley Dynamics and Marconi Space and Defence Systems Ltd. are currently engaged in the project definition phase of DTI's proposed Geostationary Technology Satellite (GTS), designed for launch on a NASA Delta vehicle towards the end of 1976.

Revised List of Miscellaneous Mines

A revised List of Miscellaneous Mines (mines of minerals other than coal, stratified ironstone, shale or fireclay) in Great Britain has been prepared by the Department of Trade and Industry. The list gives the names and addresses of 101 mines operating at September 30, 1972, as well as the names and addresses of the owners, together with details of the minerals being worked or obtained from elsewhere and dressed at one of the mines.

Copies (25p each, payable with order) from: Department of Trade and Industry, Safety and Health Division, Thames House South, Millbank, London SW1.

British Calibration Service: Approved Laboratories

A ready-reference list of laboratories approved by the British Calibration Service to measure, to calibrate and to issue BCS Certificates of Calibration was published in *New Technology* Number 45 (April 1971), and this list was brought up to date in *New Technology* Numbers 49 (August 1971), 52 (November 1971) and 59 (June 1972). Since then, the following additional laboratories have received BCS approval. The measurement category is given first, followed by the name of the laboratory, the address of the parent organisation, and the name and the telephone number of the head of the laboratory.

Electrical (dc and lf)

Calibration Laboratory,
C. and N. Electrical Industries Ltd.,
Monkmoor Road,
Shrewsbury,
Shropshire SY2 5SU.
Mr. B. Fogarty,
Shrewsbury 56343.

Instrument Calibration Laboratory,
Sperry Rand Ltd.,
Gyroscope Division,
Downshire Way,
Bracknell,
Berkshire RG12 1QI.
Mr. L. J. Thomas,
Bracknell 3222.

Electrical Standards Laboratory,
Department of Electrical and Electronic Engineering,
Portsmouth Polytechnic,
Anglesea Road,
Portsmouth,
Hampshire PO1 3DJ.
Mr. R. Walker,
Portsmouth 27681.

Standards and Calibration Laboratory,
Department of Electrical Engineering,
University of Aston in Birmingham,
Sumpner Building,
19 Coleshill Street,
Birmingham,
Warwickshire B4 7PB.
Mr. R. Turner,
021-359 3611.

Mechanical

RFL Standards Laboratory,
United Kingdom Atomic Energy Authority,
Reactor Group,
Springfields,
Salwick,
Preston,
Lancashire PR4 0RR.
Mr. I. C. Campsie,
Preston 729351

Calibration Facilities,
Avery-Denison Ltd.,
Moor Road,
Leeds,
Yorkshire LS10 2DE.
Mr. C. D. Thompson,
Leeds 708111.

Calibration Facilities,
Surface Flatness Company,
Union Mill Industrial Estate,
Manchester Road,
Mossley,
Lancashire.
Mr. E. S. Ashworth,
Mossley 2893.

Optical

Calibration Laboratory,
Pye Unicam Ltd.,
York Street,
Cambridge CB1 2PX
Mr. M. E. Bond,
Cambridge 58866.

(Since November 16, 1972, Pye Unicam has ceased to operate an electrical dc and lf calibration laboratory under the BCS approval scheme.)

A number of changes in name and/or address have taken place. The new correct details for the organisations concerned are:

Mechanical Measurements Laboratory,
GEC Power Engineering Ltd.,
Stafford, and
English Electric Co. Ltd.,
Stafford Engineering Products Division,
Stafford.
Mr. C. T. B. Moore,
Stafford 3232.

Standards Laboratory,
H. W. Sullivan Ltd.,
Dover,
Kent.
Mr. J. R. Stallwood,
Dover 2626.

Mechanical Measurements Laboratory,
Naval Ordnance Services Establishment,
Janson Street,
Sheffield,
Yorkshire S9 2LJ.
Mr. R. R. Butters,
0742 49261.

Electrical Measurements Laboratory,
Naval Ordnance Services Establishment,
Janson Street,
Sheffield,
Yorkshire S9 2LJ.
Mr. R. R. Butters,
0742 49261.

More information: Where possible, items in *New Technology* indicate the best sources of further information. Readers are advised also to seek information on matters relating to *New Technology* from the following DTI regional offices: Edinburgh, 031-225 1822; Cardiff 62131; Newcastle upon Tyne 27575; Manchester, 061-832 9111; Leeds 38232; Nottingham 46121; Birmingham, 021-643 8221; Bristol 21071; London and South East, 01-684 9781; Eastern, 01-828 4355. In Northern Ireland, information is given by the Dept. of Industrial and Forensic Science, Belfast 645421.

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